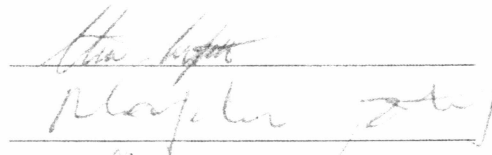


FOXTAIL BARLEY (*HORDEUM JUBATUM*) CONTROL WITH  
PROPOXYCARBAZONE-SODIUM AND FLUAZIFOP-P-BUTYL IN THREE  
ALASKA NATIVE GRASS SPECIES

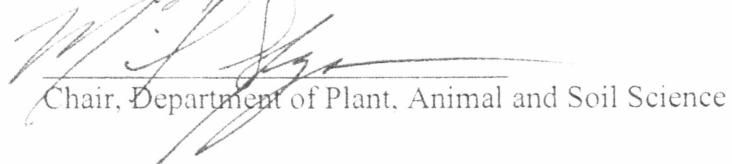
By

Brian Earl Jackson

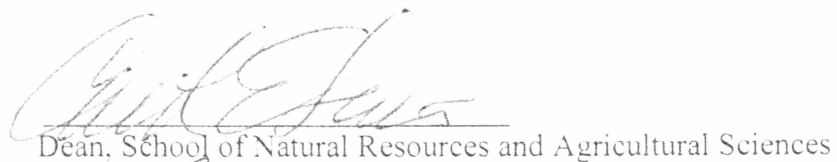
RECOMMENDED:

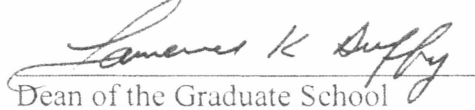


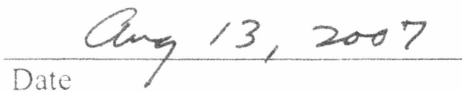
Advisory Committee Chair

  
Chair, Department of Plant, Animal and Soil Science

APPROVED:

  
Dean, School of Natural Resources and Agricultural Sciences

  
Dean of the Graduate School

  
Date

FOXTAIL BARLEY (*HORDEUM JUBATUM*) CONTROL WITH  
PROPOXYCARBAZONE-SODIUM AND FLUAZIFOP-P-BUTYL IN THREE  
ALASKA NATIVE GRASS SPECIES

A  
THESIS

Presented to the Faculty  
of the University of Alaska Fairbanks

in Partial Fulfillment of the Requirements  
for the Degree of

MASTER OF SCIENCE

By

Brian Earl Jackson, B.S.

Fairbanks, Alaska

August 2007

ALASKA  
QK  
495  
G74  
J33  
2007



## ABSTRACT

Foxtail barley is one of the most detrimental weeds for the Alaska native grass seed industry. Its control is essential for improving seed production and stand longevity so producers can meet statewide seed demands. The objective of this study was to determine suitable chemical controls of foxtail barley for three different native grass species: 'Nortran' tufted hairgrass (*Dechampsia caespitosa* L.), 'Gruening' alpine bluegrass (*Poa alpina* L.), and 'Wainwright' slender wheatgrass (*Elymus trachycalus* L.) formerly (*Agropyron pauciflorum* L.). Field and greenhouse experiments were performed to identify selectivity between two herbicide compounds and the crops studied. Foxtail barley was extremely sensitive to both compounds at the 1X rate whereas 'Nortran' tufted hairgrass was tolerant of propoxycarbazone. 'Gruening' alpine bluegrass and 'Wainwright' slender wheatgrass were not tolerant of either compound at the full rate but showed greater tolerance of propoxycarbazone at the 1/2X rate. Propoxycarbazone is a potential tool for foxtail barley control in all three native grass species used for seed production in Alaska.

## ACKNOWLEDGEMENTS

This project would not have been possible without the support of many people. Many thanks to my advisor, Stephen D. Sparrow, who read my numerous revisions and helped me personally, professionally and academically throughout this process. Also thanks to my committee members, Steven S. Seefeldt and Mingchu Zhang, who offered guidance in experimental design and statistical analysis as well as overall academic support. I would also like to acknowledge darleen masiak, Bob VanVeldhuizen and Erin Carr for their assistance in the field as well as their support and encouragement, especially throughout the writing process.

Thanks to the Alaska Seed Growers Association for providing us with the financial means to complete this project. Thanks to the Graduate School and the Provost for providing me with funding for travel to the Western Society of Weed Science conference. And finally, thanks to my friends and family who endured this long process with me, always providing support and understanding.

## TABLE OF CONTENTS

	Page
SIGNATURE PAGE.....	i
TITLE PAGE.....	ii
ABSTRACT .....	iii
ACKNOWLEDGMENTS.....	iv
TABLE OF CONTENTS .....	v
LIST OF FIGURES .....	viii
LIST OF TABLES .....	ix
CHAPTER 1 INTRODUCTION .....	1
‘Nortran’ Tufted Hairgrass ( <i>Deschampsia caespitosa</i> L.) .....	1
‘Gruening’ Alpine Bluegrass ( <i>Poa alpinia</i> L.) .....	2
‘Wainwright’ Slender Wheatgrass ( <i>Elymus trachycalus</i> L.) .....	2
Foxtail Barley ( <i>Hordeum jubatum</i> ).....	3
Herbicides and Their Modes of Action.....	5
Amino Acid Synthesis Inhibitors.....	5
Lipid Synthesis Inhibitors.....	6
Seedling Shoot Growth Inhibitors.....	7
Preliminary Trials .....	8
Fluazifop-p-butyl (Fusilade®).....	10
Propoxycarbazone-sodium (Olympus™).....	10
Final Studies .....	11

Literature Cited.....	13
CHAPTER 2 SENSITIVITY OF FOXTAIL BARLEY (HORDEUM JUBATUM) AND THREE ALASKA NATIVE GRASS SPECIES TO PROPOXYCARBAZONE AND FLUAZIFOP.....	18
Abstract .....	18
Introduction .....	19
Materials and Methods.....	20
Results and Discussion.....	23
Propoxycarbazone-sodium Rate Response and Species Tolerance .....	23
Fluazifop-p-butyl Rate Response- Species Tolerance .....	25
Literature Cited.....	28
CHAPTER 3 IDENTIFYING WHEN TO MEASURE PLANT-HERBICIDE INTERACTIONS THROUGH TIME OF FOUR NATIVE ALASKA GRASSES TREATED WITH FLUAZIFOP OR PROPOXYCARBAZONE.....	29
Abstract .....	29
Introduction .....	30
Materials and Methods.....	32
Results and Discussion.....	34
Fluazifop.....	35
Propoxycarbazone.....	36
Summary and Conclusions.....	38
Literature Cited.....	39
CHAPTER 4 DOSE RESPONSES OF FOUR NATIVE ALASKA GRASS SEEDLINGS IN GREENHOUSE STUDIES TO PROPOXYCARBAZONE AND FLUAZIFOP.....	40

	Page
Abstract .....	40
Introduction .....	41
Materials and Methods.....	42
Results and Discussion.....	44
Fluazifop.....	44
Propoxycarbazone.....	46
Application Timing .....	47
Harvest Timing .....	47
Literature Cited.....	49
CONCLUSION.....	51
Applied Impacts From the Study .....	53
Future Research .....	55

## LIST OF FIGURES

Figure 1.1 Study Site Locations.....	16
Figure 1.2 Chemical structure of fluazifop-p-butyl .....	17
Figure 1.3 Chemical structure of propoxycarbazone-sodium .....	17
Table 2.1 Visual rating scale and definitions used in the foxtail barley control study in Delta Junction and Fairbanks, AK. ....	22
Figure 2.1 Dose response curves for Gruening alpine bluegrass (GAB), Wainwright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) following treatments of propoxycarbazone at 8 WAT in Fairbanks.....	24
Figure 2.2 Visual ratings of native grass crop injury and foxtail barley control as influenced by propoxycarbazone concentrations.....	25
Figure 2.3 Dose response curves for Gruening alpine bluegrass (GAB), Wainwright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) following treatments of fluazifop at 8 WAT in Fairbanks. ....	26
Figure 2.4 Visual ratings of native grass crop injury and foxtail barley control as influenced by fluazifop concentrations .....	27
Table 3.1 Visual rating scale and definitions .....	34
Figure 3.1 Native grass crop injury and foxtail barley control as influenced by fluazifop over time. ....	36
Figure 3.2 Native grass crop injury and foxtail barley control as influenced by propoxycarbazone over time.....	37
Figure 4.1 Dose response curves for Gruening alpine bluegrass (GAB), Wainwright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) when subjected to 6 different concentrations of fluazifop at 2 (WAT).. ....	45
Figure 4.2 Dose response curves for Gruening alpine bluegrass (GAB), Wainwright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) when subjected to 6 different concentrations of propoxycarbazone at 2 (WAT).....	46

**LIST OF TABLES**

Table 2.1 Visual rating scale and definitions used in the foxtail barley control study in Delta Junction and Fairbanks, AK.....	22
Table 3.1 Visual rating scale and definitions.....	34

## CHAPTER 1

### Introduction

"The right dose differentiates a poison and a remedy." -Paracelsus

Native grass seed has been produced in Alaska since at least 1965 when the University of Alaska Agricultural Experiment Station and the U.S. Department of Agriculture released 'Arctared' Red Fescue *Festuca rubra* (Alaska Plant Material Center, 2005a). Since then several other cultivars have been released with characteristics specific to different regions in Alaska. Some of the uses for these native grasses are erosion control, revegetation and residential turf. The native seed industry provides a market specifically for local producers and receives a substantial premium for its product. The industry suffers from extreme yield variability and a host of pests that reduce yields or stand longevity. Foxtail barley has been identified as the most problematic grassy weed in Alaskan native grass seed production fields (Conn, personal communication 2004). In this study three native grass seed crops were selected because of their importance to the native grass seed industry in Alaska.

#### **'Nortran' Tufted Hairgrass** (*Deschampsia caespitosa* L.)

Nortran tufted hairgrass is found throughout Alaska, (Hultén, 1968) and is well suited for many of Alaska's harshest environments. It is a cool season grass and will grow in most soil conditions. Nortran is resistant to toxic wastes, and is therefore often used in the reclamation of mining sites (Alaska Plant Material Center, 2005c). It is also recommended for the reclamation of subalpine, alpine, and mountain meadow habitats.



It is not recommended for revegetation of stream bank areas, since the tufted fibrous roots provide limited bank stabilization (Mitchell, 1986). Nortran is a long lived perennial, with a life expectancy of up to 20 years.

**‘Gruening’ Alpine Bluegrass** (*Poa alpinia* L.)

*Poa alpina* is native to Alaska (Hultén, 1968) and is considered an alpine and low Arctic species. It is a perennial bunch grass that only reaches 10 - 40 cm in height. Gruening germinates readily and can be established on disturbed, gravelly, low nutrient sites. In production systems, alpine bluegrass can be seeded in the spring or fall, and can be harvested in late June or early July (Alaska Plant Material Center, 2005b).

**‘Wainwright’ Slender Wheatgrass** (*Elymus trachycalus* L.)

*Elymus trachycalus* L. (originally identified as *Agropyron pauciflorum*) is found in Alaska in dry open soils, subalpine meadows, riverbanks, and hillsides (Hultén, 1968). Slender wheatgrass is a short lived perennial, which starts growth after snowmelt, with seeds maturing in September (Plant Material Center, 2005e). It reproduces by both seeds and tillers. Wainwright works well in seed mixes since its seedlings are vigorous and because of its relatively short life span. Wainwright helps colonize and stabilize an area, then dies back and allows other plants to become established.

**Foxtail Barley (*Hordeum jubatum*)**

Foxtail barley, native to western North America, is a shallow rooted, perennial bunchgrass known for its ability to tolerate saline soils but is capable of succeeding in a variety of soil types (Best et al., 1978). It grows 30 to 60 cm tall, and produces a nodding pale green to purple, bushy spike that fades into a tawny color and becomes very brittle at maturity. The heads shatter readily and the seeds are scattered as they mature with the joints of the rachis and their three attached spiklets falling apart (Montgomery, 1964). Seeds are elliptic, yellowish brown, 60 mm long with four to eight awns and have sharp, backward-pointing barbs (Hultén, 1968). Leaf blades are 0.3 to 0.6 cm wide and are grayish green with a rough texture. The sheath margin has numerous soft hairs while the awns are up to 8 cm long. Foxtail barley propagates mainly by seeds that germinate in either the fall or spring. Over-wintered seedlings and mature plants resume growth in early spring providing a competitive advantage over many slower developing crops and plant communities (Blackshaw et al., 1999). Foxtail barley is one of the most troublesome weeds in conservation tillage cropping systems in southern Canada (Derkson et al., 1996).

Conn and Deck (1995) reported that up to 67% of seeds remain viable during the first year in the soil; while germinability decreases with time and burial and less than one percent of the buried seed remain viable after seven years. Seed germination is inhibited by warm temperatures and only occurs from a depth of less than 8 cm of soil. Seeds require a period of darkness for germination (Badger and Ungar, 1994).

Foxtail barley is common on roadsides, waste ground, open fields, and is most prevalent on soils with a high water table and high salinity (Badger and Ungar, 1990). The current range of foxtail barley includes most of the United States except for the south Atlantic and Gulf Coast states (IT IS, 2002). Herbarium records show that foxtail barley is most likely to have been present in eastern interior Alaska prior to significant human contact however, it appears to have spread dramatically in the last half century associated with accelerated human disturbances (ALA, 2007).

Foxtail barley is also troublesome to wild and domestic animals; because mature plants have long spiked awns that burrow into the soft tissues of the mouth, throat, nose and feet. Infection following injury from foxtail barley has been reported to cause calf diphtheria, lumpy jaws and puss forming abscesses that can lead to severe weight loss and death (Cords, 1960). Foxtail barley also harbors several pathogens such as wheat rust and the blackstem rust of grains (Best et al., 1978).

Foxtail barley is not a problem in agronomic systems that use conventional tillage. Tillage is an effective control practice for foxtail barley since the plant has a small, shallow root system that is susceptible to soil disturbance so burying the seeds reduces its prevalence. In cropping systems that do not include annual tillage, use of herbicides for control is necessary. Farmers growing leguminous crops such as alfalfa and clover have several foxtail control options through the use of several selective grass herbicides that provide excellent control of foxtail barley. However, control of foxtail barley in perennial grass crops is more difficult.

In order to allow Alaskan native grass seed producers to meet Alaska's seed demands, it is essential that foxtail barley be controlled to provide enhanced stand longevity as well as increased seed production. After a thorough literature review, five herbicides were selected based on mode of action and selectivity and were evaluated in preliminary trials. The herbicides selected were: fluazifop-p-butyl, propoxycarbazone-sodium, pronomide, mesosulfuron-methyl, and imazapic respectively.

### **Herbicides and Their Modes of Action**

Each herbicide has a specific mode of action which refers to the sequence of events from absorption into the plant until plant death; it is the biological reason for the plant's death or injury. When selecting the first five compounds for preliminary tests, we chose three different modes of action: amino acid synthesis inhibitors, lipid synthesis inhibitors, and seedling shoot growth inhibitors. Within each mode of action there are specific sites of action, which are the explicit targets of the herbicide.

### **Amino Acid Synthesis Inhibitors**

Site of Action- *Acetyl Lactate Synthase (ALS)*

The ALS inhibiting herbicides have a broad spectrum of selectivity and are used at low rates as soil applied or postemergence treatments in a variety of crops. These herbicides inhibit the activity of the ALS enzyme, which is involved in the synthesis of the branch chain amino acids (leucine, isoleucine, and valine) (Park and Mallory-Smith, 2004).

Amino acids are essential building blocks in proteins and are required for production of new cells. Acetyl Lactate Synthase inhibiting herbicides are readily absorbed by both

roots and foliage and translocated in both the xylem and phloem to the site of action at the growing points (Peterson et al., 2001). Selectivity is based on differential metabolism and site exclusion. The symptoms include plant stunting, chlorosis, tissue necrosis, and are normally evident within one to four weeks after application depending upon the plant species and the environmental conditions. Broadleaved plants often develop reddish veins on the undersides of leaves. Factors such as low soil moisture, high temperatures, and soil compaction can enhance the occurrence of injury or may mimic the herbicide injury.

### **Lipid Synthesis Inhibitors**

Site of Action-*Acetyl CoA Carboxylase (ACCase)*

Lipid synthesis inhibitors are primarily used in broadleaf crops for postemergence control of grassy weeds, although fluazifop-p-butyl is labeled for use in select turfgrass species. This herbicide family is highly selective and has very little broadleaf activity. Acetyl CoA Carboxylase inhibitors are absorbed through the foliage and translocated in the phloem to the meristematic regions. Meristematic activity is stopped by inhibiting the ACCase enzyme that is involved in the synthesis of lipids and fatty acids (Peterson et al., 2001). Lipids are important components of cell membranes, and without them new cells cannot be produced.

Many broadleaf herbicides can be tank mixed with these compounds to increase the spectrum of control with a single application, but tank mixing synthetic auxins with ACCase inhibitors may cause antagonism, resulting in reduced grass control with the same application rate (Iowa State Weed Science, 2005), thus to maintain acceptable

control a split application should be made or the amount of active ingredient (ai) should be increased in the tank mix.

Injury symptoms caused by lipid synthesis inhibitors are not evident until several days after treatment even though plants may quit growing directly after application. Since ACCase inhibitors act at the growing point of grass plants, injury symptoms can be diagnosed by pulling leaves out of the whorl and inspecting for necrosis from within the whorl.

### **Seedling Shoot Growth Inhibitors**

#### *Site of Action- Unknown*

Members of this herbicide family, also known as the acetamides, inhibit root and shoot growth causing stunted, malformed seedlings. The specific site of action of this herbicide family is unknown (Boerboom, 1999). Normal cell division, cell elongation, and protein synthesis are potentially inhibited. The herbicides must be present during early germination and growth of weeds to provide effective control. These herbicides are primarily effective on annual grass seedlings but some have an effect on certain broadleaves as well. Soil moisture, pH, and organic matter all play important roles in the phytotoxicity of soil applied herbicides.

Boerboom (1999) noted that injury symptoms include improper leaf unfurling in grasses or leafing out underground. Broadleaves will have shortened midveins causing the leaf to have a heart shaped appearance, also referred to as a drawstring appearance.

## Preliminary Trials

Initial trials were performed in pre-existing farmers' fields in the Delta Junction and the Eielson Farm area, near Fairbanks in central Alaska (Figure 1.1). The herbicides we used were: *fluazifop-P-butyl* [Butyl(R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy] propionate] an ACCase inhibitor, *imazapic* [(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid] an ALS inhibitor, *pronomide* [3,5-dichloro-n-(1,1-dimethyl-2-propionyl)-benzamide] a seedling shoot inhibitor, *propoxycarbazone-sodium*, Methyl 2-[[[(4,5-dihydro-4-methyl-5-oxo-3-propoxy-1H-1,2,4-triazol-1-yl)-carbonyl]amino]sulfonyl]benzoate an ALS inhibitor and *mesosulfuron-methyl* methyl 2-[(4,6-dimethoxypyrimidin-2-ylcarbonyl)sulfonyl]-α-(methanesulfonamido)-p-toluate] an ALS inhibitor. The selected native grass crops were: 'Gruening' alpine bluegrass, 'Nortran' tufted hairgrass, and 'Wainwright' slender wheatgrass. In all experiments, the maximum recommended field use rate was considered the 1X rate and was as follows: fluazifop-p-butyl at 275 g ai ha<sup>-1</sup> plus a non-ionic surfactant (NIS) at 0.5%(vol/vol), propoxycarbazone-sodium at 44 g ai ha<sup>-1</sup> plus NIS at 0.5% (vol/vol), imazapic at 198 g ai ha<sup>-1</sup>, mesosulfuron-methyl at 15g ha<sup>-1</sup> plus NIS at 0.5%(vol/vol) and 3.4 kg ai ha<sup>-1</sup> of sprayable ammonium sulfate (AMS), and pronamide at 420 g ai ha<sup>-1</sup>. Several trials were set up on each farm, each in a randomized complete block design. Each block consisted of five, 2 x 4 m strips. Herbicide applications were made using a variable rate log-step sprayer. The log-step sprayer has a 1.3 meter application pattern and used four 8002 VS Tee-jet nozzles with thirty inch flat fan spray patterns. We calibrated the sprayer at a 187 l ha<sup>-1</sup> output. Each

rate was applied over a ten meter span, allowing the 50 m strips to receive five different rates: 2X, 1X, 1/2X, 1/4X, and 0X, of the labeled rate. Plots were laid out in areas of the fields that suffered from foxtail barley infestations but also had sufficient crop stands to allow for evaluations of both weed control and crop response. All herbicides were applied in mid-June with the exception of the pronomide, which was applied in the autumn after soil temperatures dropped below 13°C. We recorded visual observations on weed control and crop response every other week by recording plant cover progression or regression in 1 m<sup>2</sup> areas randomly placed in each 10 m plot. The rating system was based on a percent of cover scale and is as follows: 1= (0-20%) 2= (21-40%) 3= (41-60%) 4= (61-80%) 5= (81-100%). These observations led to the elimination of imazapic, pronomide, and mesosulfuron-methyl from future studies due to unacceptable crop response including: reduced stands, necrotic plant tissue, or severe chlorosis. Mesosulfuron-methyl was eliminated due to unacceptable crop response and a lack of weed control. The two remaining compounds: fluazifop-p-butyl and propoxycarbazone-sodium appeared to provide excellent control of foxtail barley and variable injury to the selected crop plants.



**Fluazifop-p-butyl (Fusilade®)**

Fluazifop-p-butyl (Figure 1.2) is a grass specific herbicide marketed by Syngenta under the trade name Fusilade®. Fluazifop-p-butyl is degraded primarily through microbial metabolism and hydrolysis, and is not readily photodegraded. The half-life of fluazifop-p-butyl in soil is one to two weeks. Since it binds strongly with soils, it is not highly mobile and is not likely to contaminate ground water or surface water through surface or sub-surface runoff. Fluazifop-p-butyl is readily hydrolyzed in water into fluazifop acid, which is stable. Fluazifop-p-butyl is of relatively low toxicity to birds and mammals, but can be highly toxic to fish and aquatic invertebrates.

The fluazifop molecule can take two forms, the R- and S-isomers, but only the R-isomer is herbicidally active. Older formulations of Fusilade® contained fluazifop-butyl, which contained both the R- and S- isomer. New formulations only contain the R-isomer form, and may behave differently than some of the older studies have predicted.

The ACCase inhibiting herbicides like fluazifop are considered to not pose a serious environmental threat. They are foliar applied with relatively low rates and are short lived in the soil. Fluazifop-p-butyl has low water solubility, thus it has a low leaching potential and usually degrades on site.

**Propoxycarbazone-sodium (Olympus™)**

Propoxycarbazone-sodium (Figure 1.3) is a grass specific herbicide with limited broadleaf activity. Propoxycarbazone-sodium is marketed by Bayer Crop Science under the trade name Olympus™. Olympus™ is an ALS inhibitor from the

sulfonylaminocarbonyltriazalone family and is taken up predominantly by roots but also by leaves, shoots, and is translocated acropetally and basipetally in the xylem and phloem.

Propoxycarbazone-sodium is a fairly new compound that provides some residual activity, controlling newly-emerged weeds for several weeks following application. Environmental conditions that provide the best growing conditions for crops and weeds also provide the best herbicidal activity. Olympus™ is suited for different tank mix combinations, giving it increased flexibility in different cropping systems while providing a broad spectrum of control.

Propoxycarbazone-sodium has exceptionally low mammalian toxicity and has minimal environmental concerns because of the low application rate.

### **Final Studies**

Experiments attempting to identify the dose response curves of fluazifop-p-butyl and propoxycarbazone-sodium on selected native grass seedlings were performed in USDA/ARS greenhouses at the Matanuska Experiment Farm in Palmer during the winter of 2005/2006. Field studies were performed at the UAF Fairbanks Experiment Farm and the UAF Delta Junction Field Research Site during the summer of 2006. Plots were planted in fall 2005 with either ‘Gruening’ Alpine bluegrass, ‘Wainwright’ slender wheatgrass, ‘Nortran’ tufted hairgrass or foxtail barley.

Data analysis from the greenhouse studies and from field studies took place during the winter of 2006/2007. Results from these studies will provide native grass seed

producers with new management strategies for controlling foxtail barley in selective grass seed crops.

## Literature Cited

ALA. University of Alaska Herbarium. Arctos online database.

<http://arctos.database.museum/home.cfm>. (Accessed on 9 Jan. 2007).

Alaska Plant Material Center, 2005a. 'Arctared' Red Fescue *Festuca rubra*.

<http://www.dnr.state.ak.us/ag/ArctaredRedFescue.pdf> (Accessed on 10 Jan. 2007).

Alaska Plant Material Center, 2005b. 'Gruening' Alpine Bluegrass *Poa alpine*.

<http://www.dnr.state.ak.us/ag/PMCFlyers/GrueningAlpineBluegrass.pdf> (Accessed on 22 Jan. 2007).

Alaska Plant Material Center, 2005c. 'Nortran' Tufted Hairgrass *Deschampsia*

*caespitosa*. <http://www.dnr.state.ak.us/ag/NortranTuftedHairgrass.pdf> (Accessed on 22 Jan. 2007).

Alaska Plant Material Center, 2005d. 'Nugget' Kentucky Bluegrass *Poa Pratensis*.

<http://www.dnr.state.ak.us/ag/KentuckyBluegrassNugget.pdf> (Accessed on 10 Jan. 2007).

Alaska Plant Material Center, 2005e. Wainwright Germplasm slender wheatgrass *Elymus trachycalus* (*Agropyron pauciflorum*).

<http://www.dnr.state.ak.us/ag/PMCFlyers/WainwrightWheatgrass.pdf> (Accessed on 22 Jan. 2007).

Badger, K.S. and I.A. Ungar, 1990. Effects of soil salinity on growth and ion content of the inland halophyte *Hordeum jubatum*. Botanical Gazette. 151(3): 314-321.

Badger, K.S. and I.A. Ungar, 1994. Seed bank dynamics in an inland salt marsh, with special emphasis on the halophyte *Hordeum jubatum* L. International Journal of Plant Sciences. 155(1):66-72.

Best, K. F., J. D. Banting, and G. C. Bowes, 1978. The biology of Canadian weeds. 31. *Hordeum jubatum* L. Can. J. Plant Sci.

Blackshaw, R. E., G. Semach, X. Li, O'Donnovan, J. T., Harker, K. N., 1999 An integrated weed management approach to managing foxtail barley (*Hordeum jubatum*) in conservation tillage systems. *Weed Technol.* 13:347-353.

Boerboom C., 1999. Herbicide Mode of Action Reference. Available at [http://ipcm.wisc.edu/uw\\_weeds/extension/articals/herbmoa.html](http://ipcm.wisc.edu/uw_weeds/extension/articals/herbmoa.html). (Accessed on 8 June 2005).

Conn, J.S. and R.E. Deck, 1995. Seed viability and dormancy of 17 weed species after 9.7 years of burial in Alaska. *Weed Science.* 43: 583-585.

Cords, H. P., 1960. Factors affecting the competitive ability of foxtail barley (*Hordeum jubatum*). *Weeds*: 636-644.

Derkson, D. A., R. E. Blackshaw, and S. M. Boyetchko, 1996. Sustainability, conservation tillage and weeds in Canada. *Can. J. Plant Sci.* 76:651-659.

Hulten, E., 1968. *Flora of Alaska and Neighboring Territories*. Stanford University Press, Stanford, CA. 1008pp.

Iowa State Weed Science, 2005. 2005 Herbicide Manual for Ag Professionals. Ext. Pub. WC-92. ISU Ext. Agronomy, Iowa State Univ., Ames, IA.

IT IS-Integrated Taxonomic Information System, 2002. *Hordeum jubatum* L. Available: <http://www.itis.usda.gov/index.html>. Accessed on 4 December, 2006.

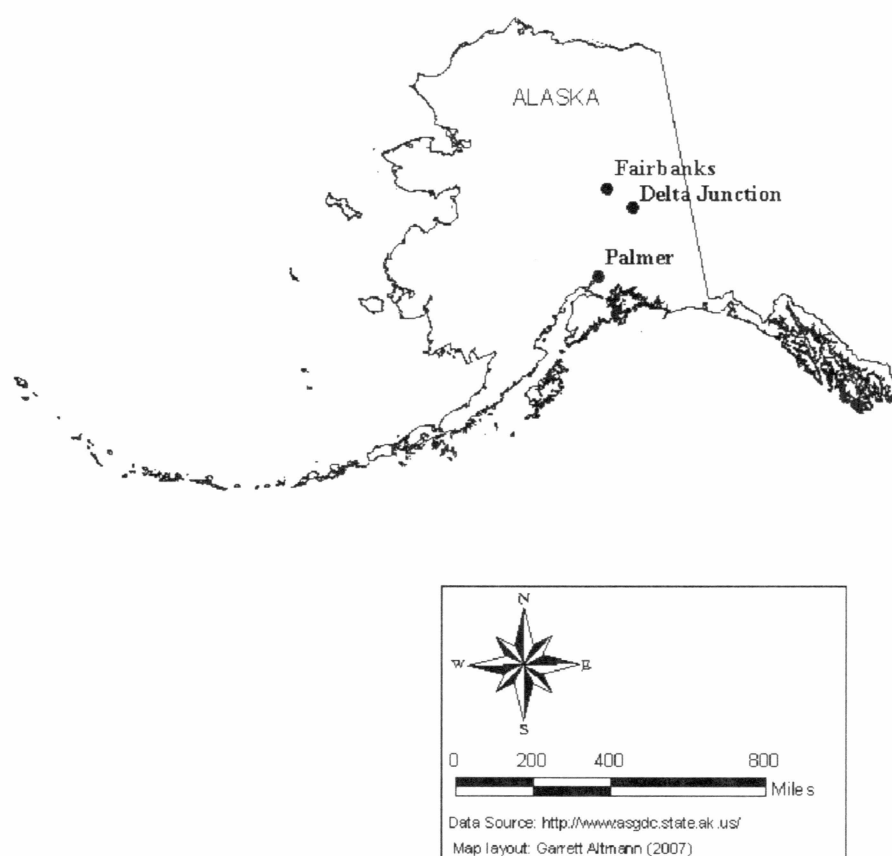
Mitchell, W., 1986. "Notice of Release of 'Nortran' Tufted Hairgrass.", *Agroborealis*, July, 1986.

Montgomery, F. H., 1964. *Weeds of Canada and the Northern United States*. The Ryerson Press, Toronto, Ont. 226 pp.

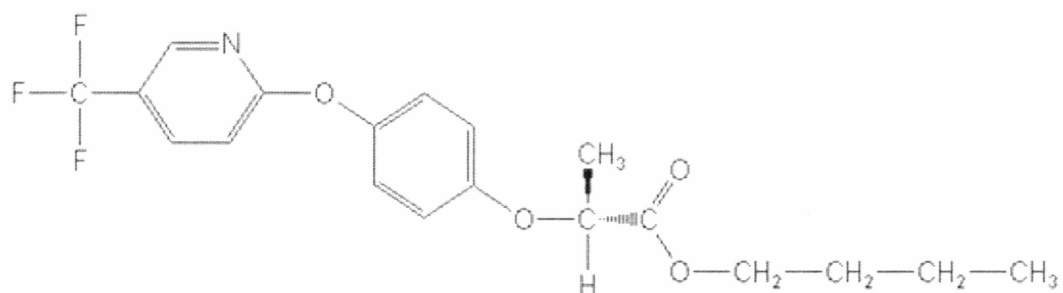
Park, K. W., Mallory-Smith, C. A., 2004. Physiological and molecular basis for ALS inhibitor resistance in *Bromus tectorum* biotypes. European Weed research Society Weed Research 44, 71-77.

Peterson, D. P., Thompson, C.R., Regehr, D. L. , Al-Khatib, K., 2001. Herbicide Mode of Action. Ext. Pub. C-715. Kansas State Univ. Ag. Exp. Sta. and Coop. Ext. Service.

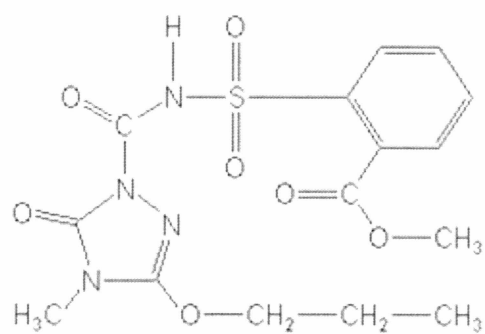
## Study Site Locations



**Figure 1.1 Study Site Locations**



**Figure 1.2 Chemical structure of fluazifop-p-butyl**



**Figure 1.3 Chemical structure of propoxycarbazone sodium**



## Chapter 2

### **Sensitivity of Foxtail Barley (*Hordeum jubatum*) and Three Alaska Native Grass Species to Propoxycarbazone and Fluazifop<sup>1</sup>**

#### **Abstract**

Controlling foxtail barley is essential for improving seed production and stand longevity in Alaska native grass seed production systems. Field experiments were conducted to investigate the selectivity of propoxycarbazone-sodium and fluazifop-p-butyl among foxtail barley and three different native Alaska grass species grown for seed. Biomass measurements were collected and visual observations were recorded on the day of application and every two weeks after treatment (WAT) until the eighth week. ‘Nortran’ tufted hairgrass, ‘Gruening’ alpine bluegrass, ‘Wainwright’ slender wheatgrass, and foxtail barley all received applications of propoxycarbazone-sodium and fluazifop-p-butyl at 1X, 1/2X, 1/4X, 1/8X and 0X of the labeled rate plus non-ionic surfactant (NIS) at 0.5% (vol/vol). Field studies were performed at the UAF Fairbanks Experiment Farm and the UAF Delta Junction Field Research Site in 2006. Foxtail barley was extremely sensitive to both compounds at the 1X rate whereas ‘Nortran’ tufted hairgrass was tolerant of propoxycarbazone. ‘Gruening’ alpine bluegrass and ‘Wainwright’ slender wheatgrass were not tolerant of either compound at the full rate but showed greater tolerance of propoxycarbazone at the 1/2X rate. Propoxycarbazone is a potential tool for foxtail barley control in all three native grass species used for seed production in Alaska.

---

<sup>1</sup> Brian E. Jackson, Stephen D. Sparrow, Steven S. Seefeldt and Mingchu Zhang, 2007. Sensitivity of Foxtail Barley (*Hordeum jubatum*) and Three Alaska Native Grass Species to Propoxycarbazone and Fluazifop. Prepared for submission in Weed Technology Journal.

## Introduction

Foxtail barley is recognized as the most problematic grassy weed in Alaska native grass seed production fields (J.Conn, personal communication, 2004)<sup>2</sup>. Foxtail barley, native to western North America, is a shallow rooted, perennial bunchgrass. Although foxtail barley is adapted to saline soils, it is capable of succeeding in a variety of soil types (Best et. Al., 1978). It grows 30 to 60 cm tall, and produces a nodding pale green to purple, bushy spike that fades into a tawny color and becomes very brittle at maturity. Foxtail barley propagates mainly by seeds that germinate in both the fall and spring. Seeds are elliptic, yellowish brown and 0.5 cm long with 4 to 8 awns which have sharp, backward-pointing barbs (Hultén, 1968).

The native grass seed industry in Alaska has room for expansion, but a lack of weed control options often results in reduced stand longevity and seed purity (P. Mulligan, personal communication, 2007)<sup>3</sup>. Tillage and glyphosate treatments are often used to control foxtail barley prior to seeding and once a stand is taken out of production (Conn and Deck, 1995). Identifying selective herbicides to control foxtail barley in different native grass species is imperative for continued growth of the seed industry. Alaska provides only a portion of the seed used in the state. Patrick Mulligan, Manager of the Alaska Seed Growers Association, estimated that in 2006 there was

---

<sup>2</sup> Jeff Conn is a Research Agronomist , United States Department of Agriculture – Agricultural Research Service – Subarctic Agricultural Research Unit, University of Alaska Fairbanks, Fairbanks AK 99775.

<sup>3</sup> Patrick Mulligan is the Manager of the Alaska Seed Growers Association.

room for at least 100% growth in sales of ‘Nortran’ tufted hairgrass and ‘Gruening’ alpine bluegrass seed as well as a slight increase in ‘Wainwright’ slender wheatgrass.

After a thorough literature review and discussion with representatives from the crop protection industry, five compounds were originally identified as potential candidates for trials. Preliminary trials resulted in the elimination of all but two compounds which led to experiments that studied propoxycarbazone and fluazifop. The objective of this study was to determine whether propoxycarbazone or fluazifop selectivity was greater for foxtail barley than for three native grasses grown for seed in Alaska.

## **Materials and Methods**

Field studies were performed at the Fairbanks Experiment Farm (latitude 65° N, longitude 148° W) and the Delta Junction Field Research Site (latitude 64° N, longitude 146° W). Soil type at the Fairbanks Experiment Farm is a Tanana mucky silt loam (coarse-loamy, mixed, superactive, subgelic Typic Aquitubels and pH 7.2). Soil type at the Delta Junction Field Research Site is Volkmar silt loam (coarse-silty over sandy or sandy skeletal, mixed, superactive Aquic Eutrocrypts and pH 4.8). (Natural Resources Conservation Service, 2007).

Field plots of slender wheatgrass, tufted hairgrass, alpine bluegrass, and foxtail barley were planted in autumn 2005 at both sites with a walk-behind cone seeder. Foxtail barley was broadcast seeded by hand and lightly incorporated by raking, since the awns prevented reasonable flow through the cone seeder. Prior to seeding, 20-10-10 (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) fertilizer was broadcast at 225 kg ha<sup>-1</sup>. The plot was then tilled using a

rotary harrow followed by a rolling basket and a soil packer to insure soil seed contact. Plots were laid out in a randomized complete block design with four replications at each site. Each replication consisted of  $2 \times 50$  m strips of 'Nortran' tufted hairgrass, 'Gruening' alpine bluegrass, 'Wainwright' slender wheatgrass, and foxtail barley and all received applications of propoxycarbazone-sodium and fluazifop-p-butyl at 1X, 1/2X, 1/4X, 1/8X and 0X of the labeled rate plus non-ionic surfactant (NIS) at 0.5% (vol/vol). Herbicide rates were based on a preliminary field study and greenhouse experiments conducted prior to this study and discussions with crop protection company representatives.

In all experiments, the maximum labeled field use rate was considered the 1X rate which was as follows: Fusilade DX® at  $1.125 \text{ kg ha}^{-1}$  (fluazifop-p-butyl  $275 \text{ g ai ha}^{-1}$ ) plus a non-ionic surfactant (NIS) at 0.5%(vol/vol), Olympus™ at  $64 \text{ g ha}^{-1}$  (propoxycarbazone-sodium  $43 \text{ g ai ha}^{-1}$ ) plus NIS at 0.5% (vol/vol). Herbicide applications were made using a variable rate log-step sprayer. The log-step sprayer had a 1.2 m boom and used 8002 VS Tee-jet flat fan nozzles. The sprayer was calibrated for an output of  $187 \text{ L ha}^{-1}$ . Each rate was applied over a 10 m span, therefore each 50 m strip received 1X, 1/2X, 1/4X, 1/8X and 0X of the recommended field rate.

Herbicide treatments were applied in the spring prior to shoot elongation. Visual observations were recorded on the day of, and every two weeks following the treatments by the same two researchers. Visual observations were made using a rating scale of 1 through 5 (Table 2.1).

**Table 2.1 Visual rating scale and definitions used in the foxtail barley control study in Delta Junction and Fairbanks, AK.**

1	No Effect	No visual symptoms on any plants.
2	Light Suppression	Plants have slight foliar symptoms, some discoloration, little foliar burn, no tissue killed.
3	Moderate Suppression	Stand reductions of ~30-50%, crop injury, tissues partially chlorotic, lasting injury.
4	Heavy Suppression	Stand reduction of ~51-80%. Severe discoloration and chlorosis. No recovery evident.
5	Death	80-100% stand reduction. Plant injury is fatal or long lasting. Excessive tissue damage and deformed new growth.

Biomass measurements were collected following the herbicide treatments, through week 8. A 25 cm × 25 cm sample area was harvested at ground level. The samples were air dried for 4 days at 60° C, and weighed. In order to compare biomass reductions among plant species the data were normalized by dividing the biomass measurements of the spray treatments by the control mean to produce a percentage of control mean value for each treatment.

To determine the relationship between the dependant variable (% of control mean), and herbicide dose for each species and herbicide these data were analyzed using a log-logistic regression model as described by Seefeldt et al. (1995).

$$y = f(x) = (C + (D - C)) / (1 + (x/I_{50})^b)$$

$$= (C + (D - C)) / (1 + \exp(b(\log(x) - \log(I_{50}))) \quad [1]$$

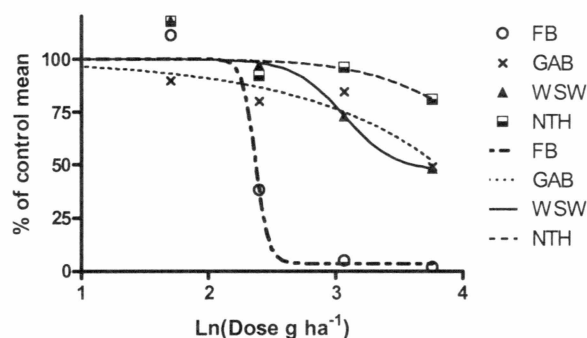
Where C = lowest mean response, D = upper limit (D was set to 100 for this study),  $b$  = slope of the line at  $I_{50}$ , and  $I_{50}$  = concentration giving 50% response or injury. The  $I_{50}$  in

this model may not be the same as the concentration that provokes a response of  $Y=50$  as the  $I_{50}$  is calculated as the midpoint between C and D and not the midpoint of 0 and 100 %. Results from the two experimental sites were analyzed separately after finding significant differences in the results by using Scheffe's post test. Differences between  $I_{50}$  values were evaluated using F-tests with two way ANOVA. Because of stand variation throughout the experiment in Delta Junction, biomass measurements were not incorporated into this paper, but visual ratings were performed at both sites and provide information on dose responses that was consistent with the biomass data. An Akaike's Information Criterion (AICc) test indicated that a linear regression model was the best fit for visual ratings, so all four species were analyzed with linear regression models.

## **Results and Discussion**

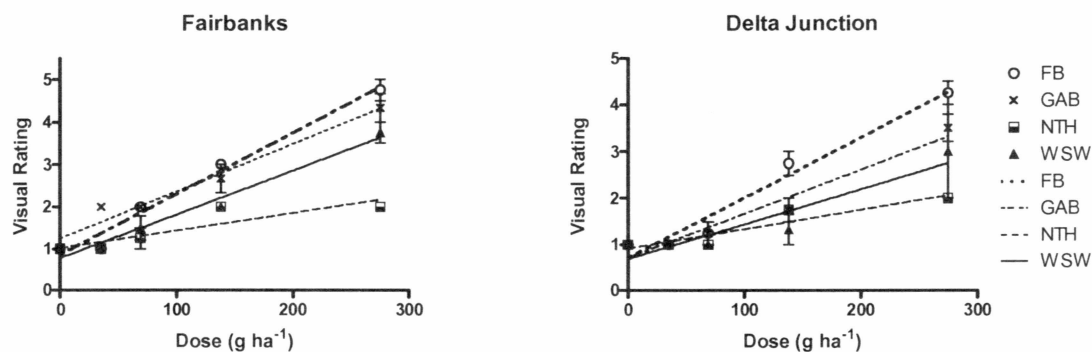
### **Propoxycarbazone-sodium Rate Response and Species Tolerance**

In Fairbanks propoxycarbazone-sodium rates of  $44 \text{ g ha}^{-1}$  provided 98% mean biomass reduction (MBR) of foxtail barley, while only reducing mean biomass of tufted hairgrass by 15% (Figure 2.1). Both slender wheatgrass and alpine bluegrass had MBR's around 50% when subjected to the 1X rate. Foxtail barley was sensitive to propoxycarbazone-sodium at the 1/2X rate with a 95% MBR, whereas the tufted hairgrass revealed no reduction in biomass at that rate. Alpine bluegrass and slender wheatgrass had 15% and 21% reductions at the 1/2X rate, indicating potential for use of propoxycarbazone-sodium in all three crops.



**Figure 2.1** Dose response curves for Gruening alpine bluegrass (GAB), Wainwright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) following treatments of propoxycarbazone at 8 WAT in Fairbanks.

Visual observations are useful for monitoring physiological alterations experienced by the different species as well as an overall comparison of plant vigor relative to herbicide dose (Figure 2.2). All species experienced either slowed or reduced heading at the 1X rate. Alpine bluegrass responded by aborting all seed heads at the 1X and 1/2X rates. Visual observations identified alpine bluegrass as a crop that will suffer from reduced seed production at rates as low as 1/8X. Tufted hairgrass was virtually unaffected by any dose less than 1X. At 8 WAT, most of the surviving plants had recovered from many symptoms or died from the herbicide exposure, making further observations unnecessary.



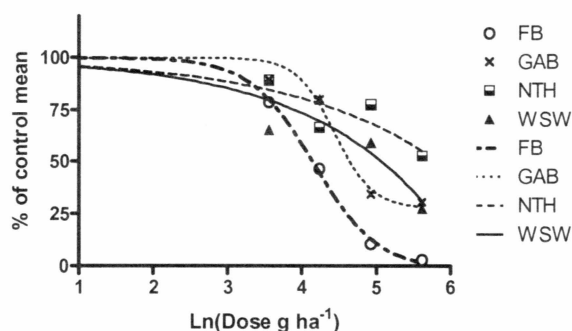
**Figure 2.2** Visual ratings of native grass crop injury and foxtail barley control as influenced by propoxycarbazone concentrations. Refer to text for complete description of the visual rating scale.  $R^2$  values : Fairbanks FB = 0.96, WSW = 0.89, NTH = 0.89, GAB = 0.91, Delta Junction FB = 0.90, WSW = 0.51, NTH = 0.73, GAB = 0.84

### Fluazifop-p-Butyl Rate Response- Species Tolerance

The 1X rate of 275 g ha<sup>-1</sup> resulted in significant MBR for all species treated (Figure 2.3).

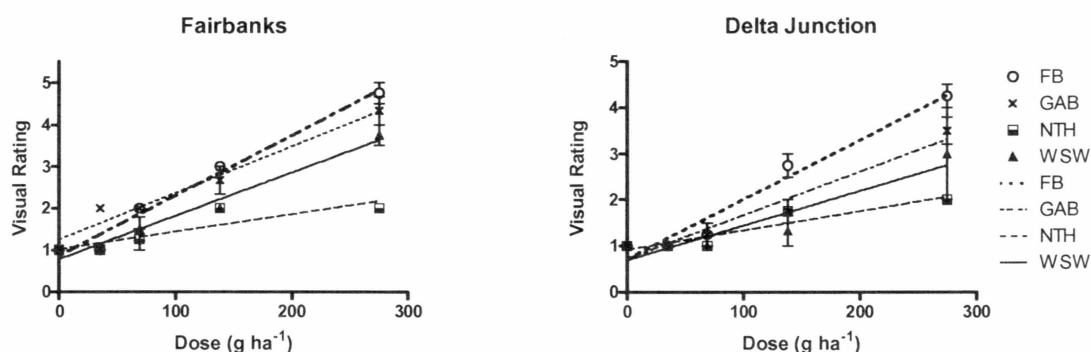
Foxtail barley showed the greatest reduction (98%), followed by alpine bluegrass and slender wheatgrass (75%), and tufted hairgrass responded least with (47%) MBR. At 140 g ha<sup>-1</sup> foxtail barley MBR was 91% but alpine bluegrass, slender wheatgrass and tufted hairgrass were also reduced by 65%, 41%, and 22% respectively, which is unacceptable in most cropping systems. Even though there was a significant difference between foxtail barley and tufted hairgrass, ( $P=0.0002$ ) the crop response was too great to consider fluazifop-p-butyl in herbicide programs on these native grasses.





**Figure 2.3** Dose response curves for Gruening alpine bluegrass (GAB), Wainwright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) following treatments of fluazifop at 8 WAT in Fairbanks.

Visual observations of fluazifop-p-butyl response at Fairbanks and Delta Junction were similar to biomass data although fluazifop had less of an effect on the alpine bluegrass in Delta Junction. The Delta Junction study site was more variable in response as is indicated by the reduced  $R^2$  values which are shown in (Figure 2.4). However, the response trends between the two sites were similar. Slight differences in application timing might account for increased variability, but soil type, fertility, moisture and differential broadleaf weed pressure may all have had an effect.



**Figure 2.4 Visual ratings of native grass crop injury and foxtail barley control as influenced by fluzifop concentrations. Refer to text for complete description of the visual rating scale.  $R^2$  values: Fairbanks FB = WSW = 0.75 NTH = 0.28, GAB = 0.41, Delta Junction FB = 0.84, WSW = 0.73, NTH = 0.16, GAB = 0.29**

In conclusion, both herbicides are effective at controlling foxtail barley in subarctic conditions; but all of the native grasses tested were injured too severely to consider fluzifop a viable option in any production system. Propoxycarbazone-sodium at either 44 g ai ha<sup>-1</sup> or 22 g ai ha<sup>-1</sup> provide good to excellent foxtail barley control without severely injuring tufted hairgrass. Slender wheatgrass and alpine bluegrass were both sensitive to propoxycarbazone at the recommended field use rate but there may be options for applications at lower rates, although further research is needed to determine proper dosages.

## Literature Cited

Best, K. F., J. D. Banting, and G. C. Bowes, 1978. The biology of Canadian weeds. 31. *Hordeum jubatum* L. Can. J. Plant Sci.

Conn, J.S. and R.E. Deck, 1995. Seed viability and dormancy of 17 weed species after 9.7 years of burial in Alaska. Weed Science. 43: 583-585.

Hulten, E., 1968. Flora of Alaska and Neighboring Territories. Stanford University Press, Stanford, CA. 1008pp.

Natural Resources Conservation Service, 2007. Web Soil Survey. Available at <http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>. (Accessed on 9 January, 2007).

Seefeldt, S. S., Jensen, J. J., E. P. Fuerst, 1995. Log-logistic analysis of herbicide dose-response relationships. Weed Technol. 9:218-227.

### Chapter 3

#### Identifying when to Measure Plant-Herbicide Interactions Through Time of Four Native Alaska Grasses Treated with Fluazifop or Propoxycarbazone<sup>1</sup>

##### Abstract

When conducting herbicide efficacy research on weeds and crops in Alaska there are no guidelines to use for deciding when to measure the plant-herbicide interaction.

Typically factors such as droplet size, adjuvant selection and application timing can have an affect on herbicide activity and plant recovery however, these can be universally controlled by the researcher. Environmental inputs that are unique to a season or a region will alter the rate of herbicidal activity. During the growing season in Interior Alaska, crops receive up to 21 hours of sunlight per day which may create a unique scenario for herbicide metabolism through extended daily physiological processes. It is important for producers to understand that crops may express some type of a response to a herbicide application, but will recover within a certain time frame. The majority of the herbicidal research has been conducted at lower latitudes where crops receive fewer hours of sunlight per day. The objective of this study was to determine how long it would take an acetyl lactate synthase (ALS) inhibitor, (propoxycarbazone) and an acetyl-CoA carboxylase (ACCase) inhibitor, (fluazifop) to complete their interactions with ‘Gruening’ alpine bluegrass (*Poa alpina* L.), ‘Nortran’ tufted hairgrass (*Deschampsia caespitosa* L.), and ‘Wainwright’ slender wheatgrass (*Elymus trachycaulus* L.) formerly

---

<sup>1</sup> Brian E. Jackson, Stephen D. Sparrow, Steven S. Seefeldt and Mingchu Zhang, 2007. Identifying when to Measure Plant-Herbicide Interactions Through Time of Four Native Alaska Grasses Treated with Fluazifop or Propoxycarbazone. Prepared for submission in Weed Technology Journal.

(*Agropyron pauciflorum L.*) compared to the weed, foxtail barley (*Hordeum jubatum*) in Interior Alaska. Biomass samples and visual rankings were collected every two weeks following treatment: 2, 4, 6, 8, weeks after treatment (WAT). Based on visual ratings, after 6 weeks, all of the plants evaluated had recovered or died from the treatments, revealing that six weeks is sufficient for evaluation of the herbicides on the four grass species tested.

## **Introduction**

To help expedite field tests of propoxycarbazone and fluazifop on grasses native to Alaska, this study compared the change in dose responses at 2, 4, 6, and 8 WAT to determine when plant herbicide interactions are complete and when to evaluate herbicide trials in Alaska. Propoxycarbazone is an amino acid synthesis inhibitor and its specific mechanism of action inhibits acetyl lactate synthase (ALS). The ALS inhibiting herbicides are used at relatively low rates as post-emergent treatments in a variety of crops. These herbicides inhibit the activity of the ALS enzyme, which is involved in the synthesis of branch chain amino acids (Boerboom, 1999). ALS herbicides are readily absorbed by both roots and foliage and are translocated in both the xylem and phloem to the site of action at the growing points (Peterson et. al., 2001). Selectivity is based on differential metabolism and site exclusion. Injury symptoms caused by ALS inhibiting compounds are not apparent until several days after treatment, although susceptible plants may stop growing immediately.

Fluazifop's mode of action is lipid synthesis inhibition, while it inhibits Acetyl-CoA carboxylase (ACCase) at its site of action. ACCase inhibitors have a high degree

of selectivity with little or no broadleaf activity. These herbicides are absorbed through the foliage and translocated through the phloem to the meristematic regions (Peterson et al., 2001). These postemergence grass control herbicides stop meristematic activity by inhibiting the ACCase enzyme that is involved with the synthesis of lipids and fatty acids. Lipids are essential components of cell membranes, and without them, new cells cannot be produced. Injury symptoms caused by lipid synthesis inhibitors are not evident until several days after treatment, although the plants cease growing soon after herbicide application. Fully developed leaves will look healthy for several days after the treatment but newly emerging leaves in the whorl of the plant will pull out easily exposing necrotic tissue at the base of the leaves (Iowa State Weed Science, 2005). The plants will gradually turn purple, then brown, and ultimately die.

There have not been many field studies with fluazifop that have measured plant response over time. Harker and O'Sullivan (1993) used visual observations as well as total biomass to evaluate the efficacy of *Elytrigia repens* over time, isolating 8 days after treatment (DAT), 12 DAT and 3 months after treatment (MAT). This study concluded that 12 DAT and 3 MAT were the most accurate evaluations for determining *Elytrigia repens* sensitivity to fluazifop. Gilliam et al. (1992) conducted a study that resembled this study in that they were examining fluazifop interactions on several ornamental grasses. Although this study was conducted in Alabama, their study concluded that the 30 DAT evaluations showed the greatest response and that the grass plants had recovered from fluazifop by 60 DAT. Since neither of these studies had isolated a specific time when the chosen grasses had actually metabolized fluazifop and since

propoxycarbazone has not been subjected to any published studies, we felt it would be useful to track plant herbicide interaction by documenting visual evaluations bi-weekly through 8 WAT.

## **Materials and Methods**

Field studies were performed at the University of Alaska Fairbanks (UAF) Experiment Farm (latitude 65° N, longitude 148° W) and the UAF Delta Junction Field Research Site (latitude 64° N, longitude 146° W). Soil type at the Fairbanks Experiment Farm is a Tanana mucky silt loam (coarse-loamy, mixed, superactive, subgelic Typic Aquitubels and pH 7.2). Soil type at the Delta Junction Field Research Site is Volkmar silt loam (coarse-silty over sandy or sandy skeletal, mixed, superactive Aquic Eutrocrypts and pH 4.8). (Natural Resources Conservation Service, 2007). Randomized complete block designs with four replications were used at both locations.

Field plots were prepared in late summer 2005 by broadcasting 20-10-10 fertilizer at 225 kg ha<sup>-1</sup>. The plots were then tilled using a rotary harrow followed by a rolling basket and a soil packer. Slender wheatgrass, tufted hairgrass, and alpine bluegrass were planted July 19<sup>th</sup> in Fairbanks and July 20<sup>th</sup> in Delta Junction with a walk behind cone seeder. Foxtail barley was broadcast seeded by hand and lightly incorporated between July 25<sup>th</sup> and July 26<sup>th</sup>, since the awns prevented reasonable flow through the cone seeder at the time of the initial seeding. Plots received moisture from rainfall throughout August allowing the native grass crops to successfully germinate. Foxtail barley, which is known for having two germinating cohorts (Blackshaw et al., 1999), germinated only sparsely in the fall of 2005. The spring germinating cohorts

successfully emerged in 2006, but the fall germinated plants were more robust than the newly germinated foxtail barley at the time of the herbicide treatments.

In all experiments, the maximum labeled field use rate was considered the 1X rate and was as follows: Fusilade DX® at 1.125 kg ha<sup>-1</sup> (fluazifop-p-butyl 275g ai ha<sup>-1</sup>) plus a non-ionic surfactant (NIS) at 0.5%(vol/vol), Olympus™ at 64 g ha<sup>-1</sup> (propoxycarbazone-sodium 43 g ai ha<sup>-1</sup>) plus NIS at 0.5% (vol/vol). Herbicide applications were made using a variable rate log-step sprayer. The log-step sprayer has a 1.3 meter boom with 8002 VS Tee-jet nozzles. The sprayer was calibrated for an output of 187 L ha<sup>-1</sup>. Each rate was applied over a 10 meter span, allowing each 50 meter strip to receive five different rates: 1X, 1/2X, 1/4X, 1/8X and 0X of the maximum labeled rate. Data for fluazifop-p and propoxycarbazone were analyzed separately.

Herbicide treatments were applied in late May 2006 prior to shoot elongation. Visual observations were recorded on the day of and every two weeks following the treatments. Ni et al. (2006) used a visual rating scale to determine turf grass susceptibility to certain herbicides. We established our own definitions for visual evaluations, and ranked each plot using a rating scale shown in Table 3.1.



**Table 3.1 Visual rating scale and definitions-**

1	No Effect	No visual symptoms on any plants.
2	Light Suppression	Plants have slight foliar symptoms, some discoloration, little foliar burn, no tissue killed.
3	Moderate Suppression	Stand reductions of 30-50%, crop injury, tissues partially chlorotic, lasting injury.
4	Heavy Suppression	Stand reduction of 51-80%. Severe discoloration and chlorosis. No recovery evident.
5	Death	80-100% stand reduction. Plant injury is fatal or long lasting. Excessive tissue damage and deformed new growth.

Biomass samples were collected every two weeks following the herbicide treatments, through week 8. A 25 cm × 25 cm sample area was harvested at ground level. The samples were air dried at 60°C for four days, and weighed. The data were expressed as a percent of the control mean. We performed repeated measures 2 way ANOVAs which showed no significant differences among response curves through time. An Akaike's Information Criterion (AICc) test indicated that a linear regression model was the best fit for the visual data, so all four species were analyzed with linear regression models. Fairbanks was the only data set used because of high variability within and among plots at Delta Junction (P=0.054 for fluazifop; P=0.172 for propoxycarbazone). This inconsistency was likely caused by a high degree of soil variability in the plots.

## **Results and Discussion**

We intended to assess the amount of time it takes for plant herbicide interactions to be completed throughout this study by identifying shifts in non-linear dose response curves of the percent of control through biomass reduction, but repeated measures 2 way ANOVA indicated no significant differences among response curves through time.

After monitoring the plots throughout the season and recording visual rankings, we observed different plant herbicide interactions among species and over time. Rankings from visual observations revealed significant changes in responses to one or both of the herbicides over time. The visual observations allowed us to evaluate symptoms that were not detectable from biomass comparisons.

### **Fluazifop**

Foxtail barley response to fluazifop showed no significant change in slope over time. All three native grass crops revealed specific patterns over the time it took to metabolize fluazifop-p-butyl (Figure 3.1). At 2 WAT all of the grasses responded with their lowest mean visual rating at the 275 g ha<sup>-1</sup> rate, and they were as follows: slender wheatgrass 2.3, alpine bluegrass 2.3, and tufted hairgrass 2.0. Alternatively, all three grasses expressed the most injury during the 4 week evaluation at 4.3, 4.8, and 2.8. There was no statistical difference in the responses between the 6 and 8 WAT. All of the crop plants recovered slightly after week 4, then stabilized. This indicated an 8 WAT evaluation may not be necessary if fluazifop is used in herbicide response experiments or considered a potential antagonist in field diagnostic trouble shooting scenarios. The 6 week cut off should only be considered with fluazifop applied at similar rates under similar growing conditions.

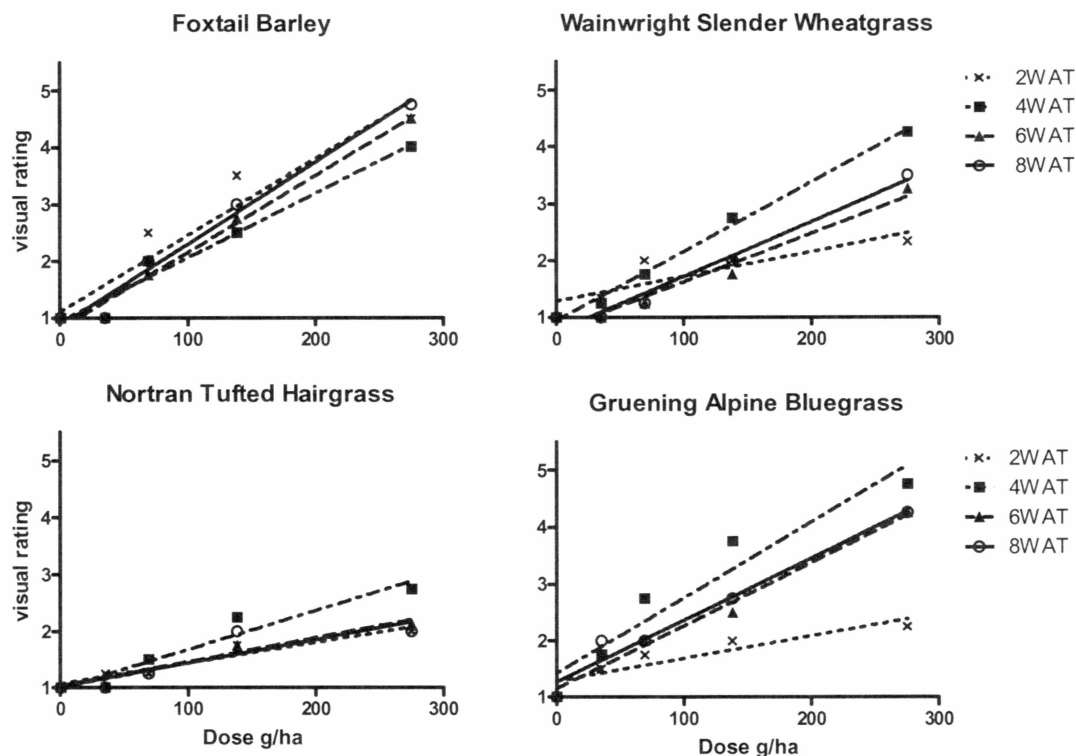


Figure 3.1 Native grass crop injury and foxtail barley control as influenced by fluazifop over time. Refer to text for complete description of the visual rating scale.  $R^2$  values : FB, 2WAT = 0.83, 4WAT = 0.86, 6WAT = 0.87, 8WAT = 0.96, WSW, 2WAT = 0.55, 4WAT = 0.90, 6WAT = 0.83, 8WAT = 0.89 NTH, 2WAT = 0.51, 4WAT = 0.74, 6WAT = 0.60, 8WAT = 0.67, GAB, 2WAT = 0.49, 4WAT = 0.85, 6WAT = 0.89, 8WAT = 0.91.

### Propoxycarbazone

Alpine bluegrass was the only species that showed a significant change over time ( $P=0.004$ ) after being treated with propoxycarbazone at  $44 \text{ g ha}^{-1}$  (Figure 3.2). The time required for the alpine bluegrass to metabolize the propoxycarbazone was similar to that of the fluazifop. At 2 WAT the alpine bluegrass had a visual rating of 2.3, and spiked to 3.5 at 4 WAT. It primarily recovered at week 6, but suspected rust in one of the replications caused the mean visual rating to increase for the last evaluation to 2.9.

Although there was no statistical difference among the slopes for the other two native grass crops, there was still a trend in mean visual rating at the 1X rate. Tufted hairgrass, and slender wheatgrass responded with their most dramatic visual ranking when evaluated at 4 WAT. Both the hairgrass and the wheatgrass showed signs of recovery at 6 WAT evaluations, while most of the foxtail barley plants were dead and no recovery was evident.

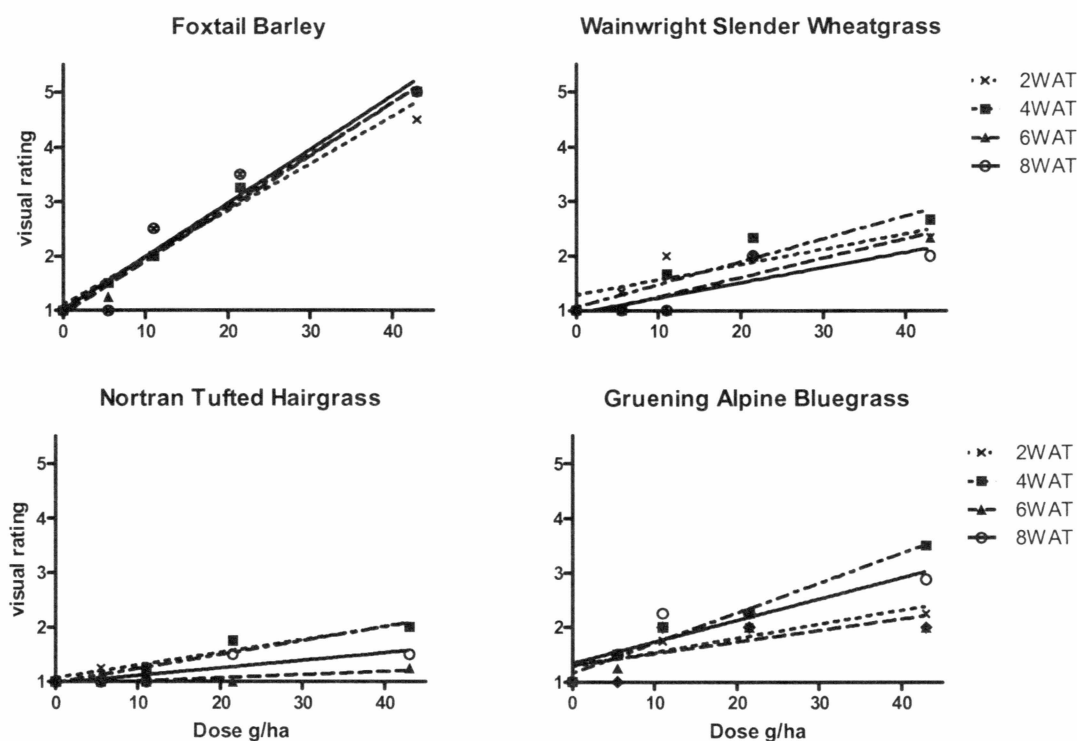


Figure 3.2 Native grass crop injury and foxtail barley control as influenced by propoxycarbazone over time. Refer to text for complete description of the visual rating scale.  $R^2$  values : FB, 2WAT = 0.84, 4WAT = 0.95, 6WAT = 0.96, 8WAT = 0.90, WSW, 2WAT = 0.55, 4WAT = 0.68, 6WAT = 0.77, 8WAT = 0.75 NTH, 2WAT = 0.50, 4WAT = 0.63, 6WAT = 0.16, 8WAT = 0.28, GAB, 2WAT = 0.49, 4WAT = 0.82, 6WAT = 0.45, 8WAT = 0.41.

## Summary and Conclusions

Foxtail barley showed no significant difference when treated with either fluazifop or propoxycarbazone at their maximum labeled rates because the two compounds had controlled the weed, so there was no opportunity for recovery. The crop plants were able to metabolize both compounds and showed primary recovery after 6 WAT at the latest. These findings will allow researchers to conclude herbicide response studies of propoxycarbazone and fluazifop at 6 WAT. Field agronomists will be able to better understand the length of time crop plants will be under stress when questioned during diagnostic trouble shooting scenarios.

## Literature Cited

Blackshaw, R. E., G. Semach, X. Li, O'Donnovan, J. T., Harker, K. N., 1999. An integrated weed management approach to managing foxtail barley (*Hordeum jubatum*) in conservation tillage systems. *Weed Technol.* 13:347-353.

Boerboom C., 1999. Herbicide Mode of Action Reference. Available at [http://ipcm.wisc.edu/uw\\_weeds/extension/articles/herbmoa.html](http://ipcm.wisc.edu/uw_weeds/extension/articles/herbmoa.html). (Accessed on 8 June 2005).

Gillam, C.H., Keever, G.J., Eakes, D.J., Fare, D.C., 1992. Postemergence applied herbicides for use on ornamental grasses. *J. Environmental Hort.* 10:136-139.

Harker, K.N. and O'Sullivan, P.A., 1993. Herbicide comparisons on quackgrass (*Elytrgia repens*) within different crop competition and tillage conditions. *Weed Sci.* 41:94-99.

Iowa State Weed Science, 2005. 2005 Herbicide Manual for Ag Professionals. Ext. Pub. WC-92. ISU Ext. Agronomy, Iowa State Univ., Ames, IA.

Natural Resources Conservation Service, 2007. Web Soil Survey. Available at <http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>. (Accessed on 9 January, 2007).

Ni, H., Wehtje, G., Walker, R., Belcher, J., and Blythe, E., 2006. Turf tolerance and Virginia buttonweed (*Dioda virginiana*) control with fluroxypyr as influenced by the synergist diflufenzopyr. *Weed Technol.* 20:511-519.

Peterson, D.P., Thompson, C.R., Regehr, D.L., Al-Khatib, K., 2001. Herbicide Mode of Action. Ext. Pub. C-715. Kansas State Univ. Ag. Exp. Sta. and Coop. Ext. Service.

## Chapter 4

### **Dose Responses of Four Native Alaska Grass Seedlings in Greenhouse Studies to Propoxycarbazone and Fluazifop<sup>1</sup>**

#### **Abstract**

Identifying minimum crop stages which allow for safe applications of certain herbicides is essential for controlling competitive weeds. Two greenhouse experiments were conducted during the winter of 2005-2006 at the Matanuska Experiment Farm in Palmer, Alaska to determine the efficacy of propoxycarbazone and fluazifop on three native Alaska grass crops, and one native grass weed. Herbicides were applied at the two or three leaf growth stage at five different rates, ranging from the recommended labeled rate to 1/16<sup>th</sup> the labeled rate, and a control treatment. The three native grass crops were 'Nortran' tufted hairgrass, 'Gruening' alpine bluegrass, and 'Wainwright' slender wheatgrass. The grassy weed studied was foxtail barley which is a perennial bunch grass that quickly establishes itself in areas of low fertility or low plant density. Foxtail barley is one of the most troublesome weeds in grass seed crops. Biomass samples were collected 2 weeks after treatment, and data were analyzed using non-linear regression. Applications of normally sub-lethal doses proved injurious to all of the studied species at early growth stages. These results provide information on timing for safe application in certain native grass seed crops.

---

<sup>1</sup> Brian E. Jackson, Stephen D. Sparrow, Steven S. Seefeldt and Mingchu Zhang, 2007. Dose Responses of Four Native Alaska Grass Seedlings in Greenhouse Studies to Propoxycarbazone and Fluazifop. Prepared for submission in Weed Technology Journal.

## Introduction

Chemical weed control is an important management component of many agricultural systems. The native seed production industry in Alaska has very few chemical options for weed control; this has resulted in shortages of native seed stock for end users.

Foxtail barley (*Hordeum jubatum*) is the most troublesome weed in the native grass seed production industry in Alaska (J. Conn, personal communication)<sup>2</sup>. Foxtail barley, native to western North America, is a shallow rooted, perennial bunchgrass known for its ability to tolerate saline soils but is capable of succeeding in a variety of soil types (Best et al., 1978). It grows 30 to 60 cm tall, and produces a nodding pale green to purple, bushy spike that fades into a tawny color and becomes brittle at maturity. The heads shatter readily and the seeds are scattered as they mature with the joints of the rachis and their three attached spiklets falling apart (Montgomery, 1964). Seeds are elliptic, yellowish brown, 0.6 cm long with four to eight awns and have sharp, backward-pointing barbs (Hultén, 1968). Leaf blades are 0.3 to 0.6 cm wide and are grayish green with a rough texture. The sheath margin has numerous soft hairs while the awns are up to 8 cm long. Foxtail barley propagates mainly by seeds that germinate in both the fall and spring (Hultén, 1968). Over wintered seedlings and mature plants resume growth in

---

<sup>2</sup> Jeff Conn is a Research Agronomist , United States Department of Agriculture – Agricultural Research Service – Subarctic Agricultural Research Unit, University of Alaska Fairbanks, Fairbanks AK 99775.



early spring providing a competitive advantage over many slower developing crops and plant communities (Blackshaw, et al., 1999). Foxtail barley is one of the most troublesome weeds in conservation tillage cropping systems in southern Canada (Derkson, et al., 1996).

Identifying herbicides that will selectively control foxtail barley in infested stands of Nortran tufted hairgrass, Wainwright slender wheatgrass, and Gruening alpine bluegrass will provide an additional option for Alaskan native grass seed producers' pest management programs. The main post emergent herbicides currently used for controlling foxtail barley include glyphosate, clethodim, fenoxypop, fluazifop-p, sethoxydim, and propoxycarbazone (Conn and Deck, 1995; Blackshaw, et al., 1999; Zollinger, 2007). These compounds are not especially selective amongst most grass species. This research includes two herbicides: fluazifop-p, and propoxycarbazone at several different concentrations to determine whether there are rates that will control foxtail barley but not injure the perennial grass seed crops at early growth stages.

## **Materials and Methods**

Two experiments were conducted during the winter of 2005/2006 in a USDA-Agricultural Research Service greenhouse located at the University of Alaska Fairbanks Matanuska Experiment Farm near Palmer, AK. The temperature in the greenhouse was maintained at 15° to 20° C with a timed lighting system providing a 12 hour day/night cycle. Supplemental lighting was not available for the first four weeks in 2005. The Alaska Plant Material Center (PMC) supplied the Wainwright slender wheatgrass, Nortran tufted hairgrass and Gruening alpine bluegrass seed. Foxtail barley seed was collected at

the University of Alaska Fairbanks Experiment Farm in September, 2005.

Commercially available potting mixes were used in 2005 and 2006. Since all herbicide applications were made post emergence it was assumed that the soil type would not significantly affect plant response to the herbicides. Three seeds were planted in each 60 ml pot. Plants were watered daily and thinned to one seedling per pot about 2 weeks after planting. Herbicides were applied at the two to three leaf stage using a handheld variable rate log step sprayer using 8002 VS Tee-jet flat fan nozzles. The sprayer was calibrated for an output of  $187 \text{ L ha}^{-1}$ . On the day of herbicide application, ten representative plants were harvested at soil level and dried at  $60^\circ \text{C}$  for 4 d. The samples were then weighed to determine base line dry weights. At 2 WAT, all plants were harvested at the soil level, dried at  $60^\circ \text{C}$  for 4 d, and weighed. Dry matter accumulation after spraying was determined by subtracting the average initial weights from the final weights of each experiment.

Both experiments were conducted using a randomized complete block design with four replications. Control plants, classified as 0X, were sprayed with water only and were included with each herbicide treatment. Herbicide concentrations were applied at 1X, 1/2X, 1/4X, 1/8X and 1/16X of the full recommended field use rate according to the label. The full recommended field use rates were: Fluzifop-p-butyl at  $275 \text{ g ha}^{-1}$  and propoxycarbazone-sodium at  $43 \text{ g ha}^{-1}$ . Ten pots were used in each replication. Dry weight data for each replication were averaged and were evaluated using F-tests with a two way ANOVA. The F-tests showed significant differences between the 2005 and 2006 experiments. An Akaike's Information Criterion (AICc) test indicated that a non-

linear dose response model with a log transformation of the dose and variable slopes would be the most accurate model. The following equation was used to fit the curves.

$$y = f(x) = (C + (D - C)) / (1 + (x/I_{50})^b)$$

$$= (C + (D - C)) / (1 + \exp(b(\log(x) - \log(I_{50}))) \quad (\text{Eq. 1})$$

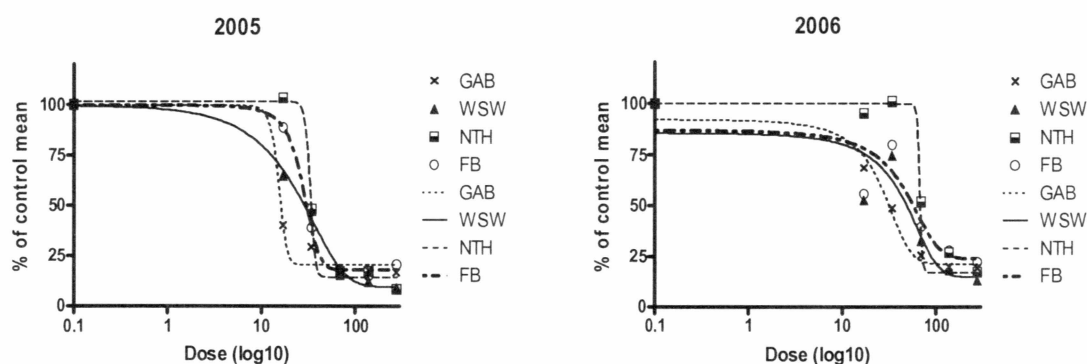
Where C = lowest mean response , D = upper limit (constrained to 100),  $b$  =slope of the line at  $I_{50}$ , and  $I_{50}$  = inhibitory concentration giving 50% response or injury (Seefeldt et al., 1995). The  $I_{50}$  in this model may not be the same as the concentration that provokes a response of  $Y=50$  as the  $I_{50}$  is calculated as the midpoint between C and D and not the midpoint of 0 and 100 %. Both of the experiments were analyzed separately as were both of the herbicides. Differences between  $I_{50}$  values were evaluated using two way ANOVA.

## Results and Discussion

### Fluazifop

$I_{50}$  values for the experiments in 2005 and 2006 were significantly different between like species ( $P=0.71$ ), but the order of sensitivity between species remained the same (Figure 4.1). Nortran tufted hairgrass was the least susceptible species whereas seedling alpine bluegrass responded with the lowest relative biomass production following fluazifop applications. Foxtail barley and slender wheatgrass responded similarly in both

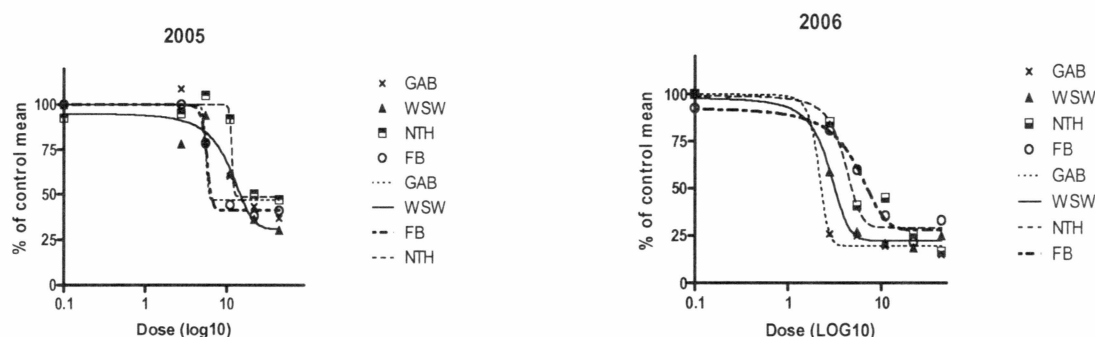
experiments. Although two way ANOVA revealed significant differences among species in both experiments, we could not decipher any potential concentrations that might select for foxtail barley without injuring any of the crop plants. Data revealed a higher tolerance to fluazifop in the 2006 experiment, compared to 2005. There were several environmental factors that could have created some of the variability. The 2005 experiment was conducted in a new greenhouse and had some inconsistent watering patterns as well as variable air movement patterns.



**Figure 4.1** Dose response curves for Gruening alpine bluegrass (GAB), Wainright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) when subjected to 6 different concentrations of fluazifop at 2 (WAT). *I*<sub>50</sub> values from each experiment: **2005**, GAB=7.45, WSW=28.51, NTH=48.15, FB=30.17, **2006**, GAB=27.24, WSW=46.11, NTH=220.3, FB=48.09.

## Propoxycarbazone

Results from the experiments in 2005 and 2006 were variable (Figure 4.2). Only the 2006 experiment showed a significant difference ( $P = 0.001$ ) among the response curves while the 2005 dataset showed no significant difference ( $P = 0.221$ ) in response curves among species. The variation between the two years was difficult to interpret since propoxycarbazone treated plants responded more dramatically in the 2006 than in the 2005 experiment. Year effect differed when comparing fluazifop with those from propoxycarbazone, with greater susceptibility in 2005 than in 2006.  $I_{50}$  values will show greater levels of sensitivity if the percent of the control mean are greater than zero, so premature harvest may have caused some of the variability between the propoxycarbazone experiments since neither of the data sets revealed enough values close to zero at the higher concentrations.



**Figure 4.2** Dose response curves for Gruening alpine bluegrass (GAB), Wainright slender wheatgrass (WSW), Nortran tufted hairgrass (NTH), and Foxtail barley (FB) when subjected to 6 different concentrations of propoxycarbazone at 2 (WAT).  $I_{50}$  values from each experiment: 2005, GAB=7.74, WSW=10.99, NTH=14.88, FB=6.22, 2006, GAB=.90, WSW=2.73, NTH=4.12, FB=4.77.

### **Application Timing**

The selected native grass species studied in these experiments mature at different rates and have varied seedling vigor (Alaska Plant Material Center a, 2005; Natural Resources Conservation Service, 1995). At the planned time of application the grasses were all at the 2 to 3 leaf stage. Although we recognized these herbicide applications were early, we knew that spraying the plants at the lower limit of maturity would allow us to determine if any growth stage should be avoided for herbicide applications. Although we had previously observed levels of tolerance among all of the crop plants tested, herbicide selectivity is often conditional, and young seedlings are usually killed more easily than more mature plants. (Radosevich et al., 1997). We believe the variable results between the 2005 and the 2006 experiments were primarily due to premature herbicide applications, but the previously mentioned environmental inconsistencies may have also added to the variability. These data provided us with a better understanding of herbicide application timing in these native grass species and indicated that fluazifop and propoxycarbazone should not be applied to the grass crops tested at the two to three leaf stage.

### **Harvest Timing**

Reviews of the literature on effects of these herbicides indicated that both herbicides would cause evident symptoms after several days in susceptible plants with growth stopping immediately after application (Iowa State Weed Science, 2005), so harvesting plants at 2 WAT appeared to be an adequate time frame for complete plant herbicide

interaction. After analyzing data from field experiments, we found that plant herbicide interactions are not complete between fluazifop and propoxycarbazone in the selected native grasses until around 6 WAT in field trails (Chapter 3). Thus premature harvest may account for some of the variability in the data. Although both herbicide labels referred to an immediate growth impediment with susceptible plants, it may take more than two weeks for a seedling plant to metabolize a particular compound and resume normal growth patterns.

## Literature Cited

- Alaska Plant Material Center, 2005a. 'Gruening' Alpine Bluegrass *Poa alpine*. <http://www.dnr.state.ak.us/ag/PMCFlyers/GrueningAlpineBluegrass.pdf> (Accessed on 22 Jan.2007).
- Alaska Plant Material Center, 2005b Wainwright Germplasm slender wheatgrass *Elymus trachycalus* (*Agropyron pauciflorum*). <http://www.dnr.state.ak.us/ag/PMCFlyers/WainwrightWheatgrass.pdf> (Accessed on 22 Jan.2007).
- Best, K. F., J. D. Banting, and G. C. Bowes, 1978. The biology of Canadian weeds. 31. *Hordeum jubatum* L. Can. J. Plant Sci.
- Blackshaw, R. E., G. Semach, X. Li, O'Donovan, J. T., Harker, K. N., 1999 An integrated weed management approach to managing foxtail barley (*Hordeum jubatum*) in conservation tillage systems. Weed Technol. 13:347-353.
- Conn. J. S. and R. E. Deck, 1995. Optimal glyphosate application time for control of foxtail barley (*Hordeum jubatum*). Weed Technol. 9:267-269.
- Derkson, D. A., R. E. Blackshaw, and S. M. Boyetchko, 1996. Sustainability, conservation tillage and weeds in Canada. Can. J. Plant Sci. 76:651-659.
- Hultén, E., 1968. Flora of Alaska and Neighboring Territories. Stanford University Press, Stanford, CA. 1008pp.
- Iowa State Weed Science, 2005. 2005 Herbicide Manual for Ag Professionals. Ext. Pub. WC-92. ISU Ext. Agronomy, Iowa State Univ., Ames, IA.
- Montgomery, F. H., 1964. Weeds of Canada and the Northern United States. The Ryerson Press, Toronto, Ont. 226 pp.
- Natural Resources Conservation Service. 1995. Seed Production for Tufted Hairgrass. Plant Materials Technical Note 16. Feb, 1995.



Radosevich, S. R., Holt, J., Ghersha, C., 1997. Weed ecology: implications for management. Pg.419-329. John Wiley & Sons, New York.

Seefeldt, S. S., Jensen, J. J., E. P. Fuerst. 1995. Log-logistic analysis of herbicide dose-response relationships. Weed Technol.9:218-227.

Zollinger R. K., 2007. North Dakota State Weed Control Guide. Available at [www.ag.ndsu.edu/weeds/w253/w253-2a.htm](http://www.ag.ndsu.edu/weeds/w253/w253-2a.htm). (Accessed on 6 April, 2007).

## Conclusion

We began a research effort in 2005 to identify herbicides for improved weed management strategies for Alaska native grass seed production. An initial literature review along with personal communication with weed scientists and industry representatives helped us identify foxtail barley as the most difficult weed to manage in native grass seed production systems in interior Alaska. Our goal was to create a management plan to control foxtail barley with selective herbicides in three native grass crop species: ‘Gruening’ alpine bluegrass (*Poa alpinia* L.), ‘Nortran’ tufted hairgrass (*Deschampsia caespitosa* L.), and ‘Wainwright’ slender wheatgrass (*Elymus trachycalus* L.). Several options for reducing foxtail barley populations are available through the use of cultural practices such as tillage and sound fertility management. These practices should be incorporated into any management recommendations for foxtail barley control.

Preliminary trials to identify herbicides that would select for foxtail barley were established in existing fields of all of the selected crops. We evaluated crop and weed responses to five different compounds: fluazifop-p-butyl, imazapic, pronimide, propoxycarbazone-sodium, and mesosulfuron-methyl which were all applied at five different rates, starting at the maximum recommended rate from the manufacturer (1X) down to 1/8<sup>th</sup> of that rate and a control (0X) treatment. Data used for evaluations was based on a percent cover rating along with general evaluations on plant health. These data revealed unacceptable crop damage or weed control for three out of the five

compounds evaluated. Two herbicides, propoxycarbazone and fluazifop-p were chosen for further study.

Two greenhouse experiments were conducted during the winter of 2005-2006 at the Matanuska Experiment Farm in Palmer, Alaska to determine the efficacy of propoxycarbazone and fluazifop on two week old seedlings of three native Alaska crop grasses and foxtail barley. Herbicides were applied at the two to three leaf growth stage at six different rates, ranging from the recommended labeled rate to 1/16<sup>th</sup> of the labeled rate, and a control treatment. Herbicide applications on young seedlings allowed us to evaluate the tolerance of the young plants to propoxycarbazone and fluazifop. We wanted to determine the earliest stages of growth that would allow safe applications since farmers often apply herbicides as early as possible to prevent the establishment of weed populations. Although we had previously observed levels of tolerance among all of the crop plants tested, herbicide selectivity is often conditional, and young seedlings are usually killed more easily than more mature vegetation. Our results indicated that fluazifop and propoxycarbazone should not be applied to the grass crops tested prior to the four leaf stage.

Field experiments to determine the effectiveness of fluazifop and propoxycarbazone on first year grasses were conducted at the Fairbanks Experiment Farm and the Delta Junction Field Research Site during the summer of 2006. Field plots of slender wheatgrass, tufted hairgrass, alpine bluegrass, and foxtail barley were planted in fall 2005 using a randomized complete block design. Herbicide applications of propoxycarbazone-sodium and fluazifop-p-butyl were made prior to shoot elongation in

the early summer of 2006. Data showed foxtail barley was extremely sensitive to both compounds at the 1X rate whereas tufted hairgrass was tolerant of propoxycarbazone. Alpine bluegrass and slender wheatgrass were not tolerant of either compound at the full rate but showed a greater tolerance of propoxycarbazone at the 1/2X rate than foxtail barley. This experiment identified propoxycarbazone as an excellent tool for foxtail barley control in tufted hairgrass seed production. Further research will be needed before we can make any strong recommendations for foxtail barley control in slender wheatgrass or alpine bluegrass.

### **Applied Impacts From the Study**

Grassy weed management strategies are currently constrained to cultural control practices along with pre-plant and post production herbicide applications for most grass seed producers in Alaska. Identifying selective herbicides that will provide producers with alternative options will improve production through improved stand establishment, higher yields, and prolonged established stands. Our research identified at least one new option for producers to control foxtail barley in tufted hairgrass and other potential options for use in other native grass seed crops.

Native grass seed stock is an important commodity for continued ecological health of Alaska. Currently, Alaska enjoys a relatively low number of non-native, invasive weed species and with current research evaluating the different corridors for which non-native species are able to enter the state, the addition of new non-native species should be further mitigated. Without suitable supplies of native grass seed

available, revegetation specialists will be forced to use imported seed in reclamation projects. The use of imported seed and non-native plants have been a source of establishment of some troublesome invasive species such as white sweetclover (*Melolotis alba*) and narrowleaf hawksbeard (*Crepis tectorum* L.) in Alaska (Jeff Conn, personal communication 2007)<sup>1</sup>. A more productive native seed industry will help insure that native germplasm is used in reclamation projects in Alaska.

The study evaluating the time it takes for the selected crop plants to recover from propoxycarbazone and fluazifop may provide valuable information for grass seed producers in specific situations where foxtail barley infestations could warrant removing a field from production for a growing season. These data show that these herbicide applications will injure the crop in the short term, but ultimately may allow the stand to stay in production for additional years. This study was specific to location, growing conditions, and crop stage at time of application expanded studies throughout Alaska's interior are to be conducted before more general recommendations can be made.

The most important information that other weed scientists might use came from the analysis performed on when to measure the plants after treatment. Evaluations of the time that it takes for plant/herbicide interactions to be completed in field studies using fluazifop-p and propoxycarbazone-sodium provide data that can now be incorporated into experimental designs by weed scientists in interior Alaska or in other subarctic regions.

---

<sup>1</sup> Jeff Conn is a Research Agronomist , United States Department of Agriculture – Agricultural Research Service – Subarctic Agricultural Research Unit, University of Alaska Fairbanks, Fairbanks AK 99775.

## **Future Research**

Weed scientists should continue studying other compounds that might select for foxtail barley in native grass seed crops. Creating a plant staging system for Alaska native grasses would be helpful for identifying lower limits of maturity for herbicide applications as well as overall simplification of communication when discussing plant maturity. Once the stages have been identified and more herbicide compounds have been recognized as potential tools for weed control in native grass seed crops, more detailed research could begin assessing crop tolerance at different growth stages. For instance, Gruening alpine bluegrass reaches an early boot stage merely days after plants visibly break dormancy in the spring which makes early herbicide applications difficult. But, this crop is harvested in early July which is much earlier than most of the other native grass seed crops. It may be that Gruening alpine bluegrass producers will have the option of safely making late season herbicide applications for foxtail barley control.

Additional research to develop better rate recommendations for the studied grass seed crops may determine different levels of susceptibility to either of the studied herbicides would potentially give producers more flexible options for foxtail barley control or suppression.

In conclusion, after two years of field trials and greenhouse experiments we discovered that propoxycarbazone-sodium is highly effective at controlling foxtail barley and had little effect on tufted hairgrass when applied after the four leaf stage. The remaining two native grass crops studied had unacceptable injury to propoxycarbazone at the 1X rate, but were more tolerant of the compound at reduced rates that were still

efficacious to foxtail barley, therefore there is potential for this herbicide to be used in all three crops studied.